Advanced Mechanical Design, University of Rochester
Gate B, Preliminary Design Report
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NOVEL MOVEMENT ROBOT

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PROBLEM DEFINITION

Problem Background:
NASA brainstorms ideas for potential rovers for other planets that have new and novel designs. These designs utilize new ways to solve a problem that are specially adapted to a particular environment. Previously, rolling robots manipulated its center of mass to invoke a rolling motion. We plan to design and manufacture a robot which deploys linear actuators to invoke a rolling motion to navigate an environment.

Problem Statement:
Today, current robots and vehicles utilize locomotion that is not advantageous to certain environments. Use of wheels or shifting center of mass run into problems traversing obstacles. Other novel ideas could exist.

Initial impression of societal, economic, environmental impact:
- The proposed shape of robot allows for increased versatility in terrain it can cross
- The locomotion of the robot can be used to reach environments not feasible to humans.
- This type of design can be used for space exploration or search and rescue missions.

Observations/Shortcomings:
- Current methods of locomotion face difficulties over certain obstacles.
- Rolling locomotion can allow for more precise movements around and/or over obstacles.
- Previous rolling robots manipulated their center of mass to create motion.
- Limited acceleration is produced from this method.

Development of a new type of movement that can evade obstacles. Opportunities/Gaps:
- Omnidirectional movement
- Proposed technology is relevant towards current engineering problems

REQUIREMENTS/SPECIFICATIONS/ DELIVERABLES

Deliverables:
- Prototype robot
- Written report
- Theory of operation manual

Initial Requirements:
- Locomotion of the robot should be novel
- General geometry of the shape will be a regular geometric object
- Actuators that allow pivoting on sides.
- Power source inside chassis (non-Tethered)

Initial Specifications:

- Cost no more than $1000 *(Budget tracking via Teams project schedule NMR)*
- Robot no larger than 4-feet *(Tape measure from side-to-side)*
- Inside volume no smaller than 8' x 11' x 14' - electrical equipment *(Tape measure)*
- Chassis weighs no more than 40lbf *(Scale)*
- Center of gravity stays within 0.5' *(Tape and Simulation)*
- Worst case floor angle of 30 degrees - assuming coefficient of friction of 0.3 *(Level it)*

CONCEPTS AND CURRENT DIRECTION OF PROJECT

- Multiple concepts were considered during the initial stage of chassis development. The team decided to stick to a semi-symmetrical shape and each member contributed by bringing up 2 unique shape ideas and presenting the pros and cons of each. The 4 shapes that were considered are hexagonal elongated bipyramid, truncated octahedron, square – orthobicupola, and small rhombicuboctahedron. The prototyping of each of the shapes was done via cardboard box paper which allowed us to quickly simulate and understand the feasibility of each shape's movement and shortcoming. The cardboard prototypes can be seen in the annex **[Figure 1].** Ideally, after discussion with our sponsor and ECE team members, these 4 design ideas were checked off and a Pugh matrix was created to select an optimal final shape **[Figure 2]**.

- A Pugh matrix was made using 5 different criteria. These criteria are ease of manufacturing, cost of manufacturing, ease of movement, number of actuators needed for optimal movement, and the possible direction of practical movement. The 5 criteria are factors that the Mechanical Engineering team and our sponsor foresaw as the most crucial aspects of chassis selection. Design 3: square – orthobicupola was selected as the optimum design as it met most of the criteria that was set for the robot. Due to symmetry and a more normal shape structure, we foresee design 3 as an easier chassis shape to manufacture. Additionally, design 3 was observed to be the most ideal for maneuverability since it allowed for 2 linear movement on the rectangular faces of its shape. The Pugh matrix is given in the annex **[Figure 2]**.

- After selecting Design 3, an NX CAD model was created to simulate movement and to capture the feasibility of adding actuators to stimulate robot maneuverability. The 3 possible areas that were considered to place actuators are the faces, edges, and vertices. It was decided that placing the actuators on the faces could result in structural issues through the consideration of the locus of rigidity. Locus of rigidity in this case is a structural term that analyzes stiffness **in the direction in which we are placing force through the faces of the chassis by the actuators.** Overall, the faces of the chassis can cause rigidity issues due to the faces not being able to sustain the linear movement. The two other considerations besides for placing actuators on the faces are edges and vertices. The two placements of actuators can be seen in the annex **[Figure 3].** Currently, we are moving towards putting the actuators on the edges (12 actuators) as opposed to putting them on the vertices (14 actuators) since it is the most practical economic decision. Actuator positioning plays a crucial role in the geometry and the motion of the robot. Until the actuator positioning was finalized, we could not yet finalize a design. We are moving towards actuators at the edges with design 3 as the most optimum design for our robot.

- Although design 3 is the most optimal some major shortcomings are observed. The actuator length for design 3 needs to be equal to the radius length of the shape to stimulate robot movement. There is not much room inside the robot chassis to store actuators that would support proper movement. We conducted some research, and a similar geometrical shape was considered. Instead of a hexagonal shape for the linear path, we decided on making the chassis base an octagon. An octagonal shape requires only 41% of the radius length to be used for actuator movement, which leaves extra room for incline maneuverability, while still saving space for internal equipment. The only downside to using an octagon is it will require 16 actuators instead of 12, which is more costly, but is the most optimal solution to our problem. The current design of the octagonal shape can be seen in the annex **[Figure 4]**.

MAJOR TASKS COMPLETED AND MAJOR TASKS TO BE DONE

- Completed:
  - Compiled requirements/specifications for Mechanical Systems expectations of robot.
  - Established work breakdown structure of Mechanical Systems for the robot.

- Established overall timeline for the project and its deliverables.
- Created initial prototypes for chassis geometry.
- Set up initial simulations for the robot's movement.

- Next Steps:
  - Complete Frankenstein model with new octagon design by simulating movement in all directions and developing skeleton layout.
  - Research and choose materials for the robot's components.
  - Perform detailed structural FEA, mechanism analysis, and fundamental statics analysis of the robot body and its actuators.
  - Complete drawings for actuator part manufacturing.
  - Establish plans for electronics and harness integration.
  - Acquire materials and tools (Actuators and Chassis)

ANNEX A

FIGURES OF DESIGNS AND SIMULATION

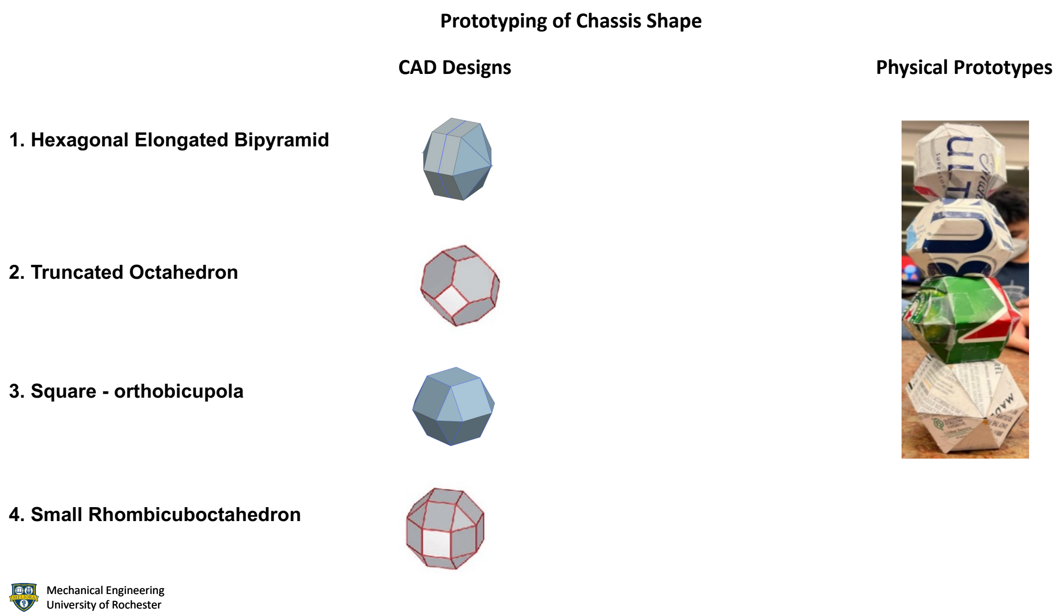

Figure 1. PDR/Prototyped designs

Design Pugh Matrix (Rate 1-3)

	Design 1 Base Model	Design 2	Design 3	Design 4
Ease of manufacturing	**0**	1	2	1
Cost of Manufacturing	**0**	2	2	2
Ease of movement	**0**	2	3	3
Number of Actuators	**0**	1	2	1
Direction of Movement	**0**	2	2	3
Total (out of 15)	**0**	8	11	10

Selected Design: Design 3 – Best feasible movement, requires less actuators, and has a moderately ease of manufacturing

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Figure 2. Pugh matrix

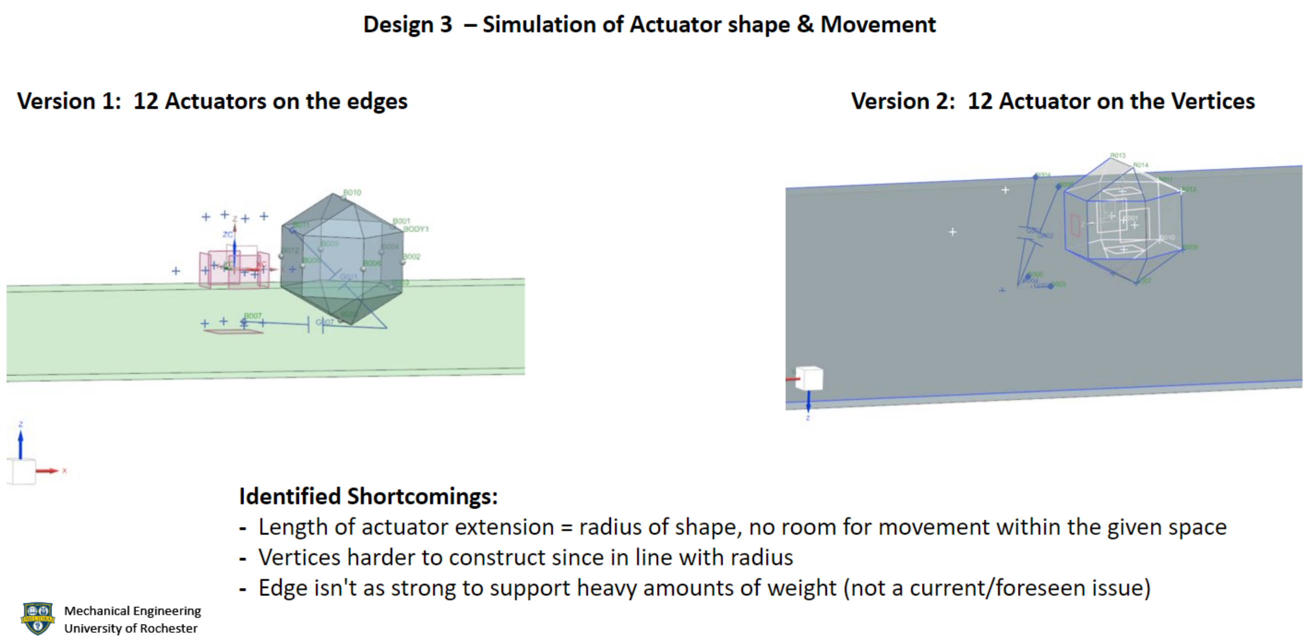

Figure 3. Actuator location and movement simulation of selected design

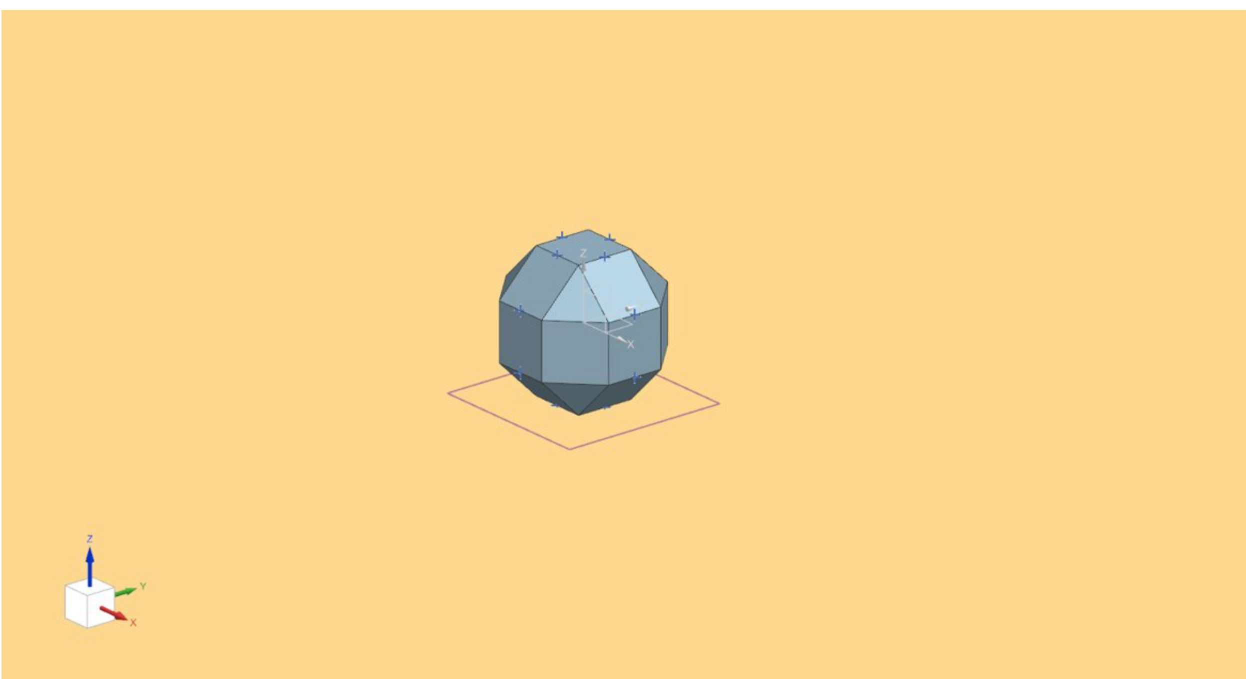

Figure 4. Current design consideration – 16 actuators on the edges